Determination of the Empirical Formula of Magnesium Oxide

Purpose:

The purpose of this experiment is to determine the empirical formula and percent yield of the ionic oxide produced by the reaction of magnesium with oxygen based on experimental data.

Hypothesis:

The empirical formula for magnesium oxide is MgO. Percent yield will be 85-100%.

Introduction:

A compound is a chemical combination of two or more elements. The formula for a compound is an abbreviation used to indicate the elemental composition and relative numbers of atoms in the compound. The formula may be an empirical formula (also called a simple formula) or a molecular formula. An empirical formula gives the simplest whole number ratio of atoms of each element in a compound. A molecular formula gives the actual number of atoms in a molecule of the compound. For example, the empirical formula of glucose is CH_2O, and its molecular formula is $C_6H_{12}O_6$. For some common compounds, the empirical formula and the molecular formula are the same. A good example is water, H_2O.

The empirical formulas of metal oxides can be determining by heating a sample of the metal in air and weighing the resulting compound. Consider the example of aluminum oxide. A sample of aluminum metal with a mass of 4.237 g is placed in a crucible and heated red hot. A white compound, aluminum oxide, forms; its mass is 8.004 g. From this information, the empirical formula of aluminum oxide can be determined.

First, the number of moles of aluminum and oxygen in the compound must be determined from their masses. The mass of aluminum is easy, 4.237 g. The rest of the mass of the compound is oxygen, 8.004 g – 4.237 g = 3.767 g.

Moles of aluminum:

$$4.237\ \cancel{\text{g Al}} \times \frac{1\ \text{mol Al}}{26.981\ \cancel{\text{g Al}}} = 0.1570\ \text{mol Al}$$

Moles of oxygen:

$$3.767\ \cancel{\text{g O}} \times \frac{1\ \text{mol O}}{15.999\ \cancel{\text{g O}}} = 0.2354\ \text{mol O}$$

Next, the mole ratio of aluminum and oxygen must be determined. Divide the smaller number of moles into the larger number.

$$\frac{0.2354\ \text{mol O}}{0.1570\ \text{mol Al}} = \frac{1.499\ \text{mol O}}{1\ \text{mol Al}}$$

The ratio must be in whole numbers, but this result is not. However, if both the numerator and denominator are multiplied by 2, the ratio is within experimental error of three moles oxygen per two moles aluminum:

$$\frac{1.499\ \text{mol O}}{1\ \text{mol Al}} \times \frac{2}{2} = \frac{2.999\ \text{mol O}}{2\ \text{mol Al}}$$

Therefore, the empirical formula of aluminum oxide is Al_2O_3. It is customary, when writing chemical formulas, to list elements in the order they appear in the periodic table, left to right.

In the experiment, you will conduct a similar experiment and calculations starting with magnesium metal. A known mass of magnesium will be heated in air and will combine with oxygen. The mass of magnesium oxide will be measured; the increase over metallic magnesium will be oxygen. The calculations will be similar to those shown above. As a prelab exercise, you will determine the empirical formula of lithium oxide.

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Safety and Waste Disposal:

In this experiment, you will be working with an electric Bunsen burner. The hazards involved with this device involve burns, either of people or objects that are not intended to be burned.

Magnesium metal is flammable. **It burns with an intense white flame** that is difficult to extinguish. Keep loose magnesium away from Bunsen burners until it is in a covered crucible. Sometimes the magnesium ignites in the course of the experiment. If it does, avoid looking at it and let it burn itself out. You can then proceed with the experiment; the ignition will not alter your results.

Do not touch the crucible with your hands (oils contaminate it and/or you could be severely burned)

Do not place a hot crucible on a lab bench (the temperature difference may cause it to break).

When you have completed your work, empty the magnesium oxide waste into the jar provided.

Procedure:

1. Obtain a crucible, cover, crucible tongs, glass rod and distilled water.
2. Place the covered crucible in the electric Bunsen burner. Heat the apparatus with the Bunsen burner for 3 mins at about 8.
3. Turn off Bunsen burner and remove crucible to the wood block. Allow the crucible to cool. When it is cool enough to touch, **obtain the mass of the empty crucible and cover.** Handle the dried crucible and cover with clean, dry, crucible tongs.
4. Measure a strip of magnesium metal ribbon about **1.5 - 2 g.** Cut the strip of magnesium into **pieces** approximately 1 cm long; don't be fussy about this, close counts.
5. Place the cut-up magnesium in the crucible and **obtain the mass of the crucible, cover, and magnesium.**
6. Place the covered crucible in the burner and heat it gently (adjust the burner to about 3-4) for about 1-2 minutes, use the crucible tongs to displace the lid so the opening is about 3-8 mm at its widest point to allow more air into the crucible
7. Then Heat strongly (adjust for to 9-9.5) until all the magnesium turns into gray-white powder (probably around 4-6 minutes). Turn off Bunsen burner, let set until not glowing, then remove crucible to the wood block. Allow the crucible to cool.
8. Break up any lumps with a glass rod. Add 10-20 drops of distilled water to the magnesium oxide. This will decompose any magnesium nitride that has formed as a side reaction to the oxidation. Replace the lid, slightly displaced, and heat the crucible again, first gently for about 1 minute then strongly for about 4-6 minutes. The bottom of the crucible may become red during this heating. Turn off the burner and remove crucible to the wood block. Allow the crucible to cool.

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9. Remove the cover and check the contents of the crucible. The magnesium oxide should appear as a gray or white powdery material. If it does, obtain the mass of the covered crucible and its contents. Otherwise, break up any lumps with a glass rod, add 10 more drops of water (rinse any residue on the rod into the crucible) and heat again as in the previous step. Repeat this until the magnesium oxide is gray or white, with no remaining metal.
10. When you have obtained the mass of the crucible and magnesium oxide, make the calculations to determine the empirical formula of the compound.
11. When you have finished the experiment, put the magnesium oxide in the waste jar. Wash the crucible and lid and blot them dry with a paper towel. Return the crucible, lid, and crucible tongs to the supply area. The Bunsen burner and scale stays at the bench.

REPORTING RESULTS

Complete your lab report (as instructed).Report the following information for each trial and for the average of the data. Show sample calculations in a separate section.

CALCULATIONS

1. mass of Mg metal used to ± 0.0001 g
2. theoretical yield of MgO from reaction: $2\ Mg_{(s)} + O_{2(g)} \rightarrow 2\ MgO_{(s)}$to ± 0.0001 g
3. mass of oxide product formed to ± 0.0001 g
4. mass of O incorporated (by difference; see eq. 4a and 4b) ±0.0001 g
5. mole ratio of Mg-to-O (four significant figures each)
6. percent by mass of Mg and O in the oxide (four significant figures)
7. empirical formula of the oxide (lowest whole-number subscripts)
8. percent yield of $2\ Mg + O_2 \rightarrow 2\ MgO$ (actual yield/theoretical yield) × 100% (to four sigfigs)

Discussion/Conclusions

How does your experimental empirical formula compare to the theoretical empirical formula — do they match?

What are primary sources of experimental error?

How would factors such as incomplete conversion of Mg_3N_2 to MgO or residual $Mg(OH)_2$ in the product affect your results?

Does this method appear to be a valid way to determine the formula of metal oxides?